ECF-HANFORD-18-0049
Revision 0

Hydraulic Gradients and Velocity Calculations for RCRA Sites in 2018

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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ENVIRONMENTAL CALCULATION COVER PAGE

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SECTION 5 - Applicable if Calculation is a Risk Assessment or Uses an Environmental Model

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Terms

EDA	Environmental Dashboard Application
IDF	Integrated Disposal Facility
LLBG	low-level burial ground
NRDWL	Nonradioactive Dangerous Waste Landfill
P&T	pump and treat
RCRA	*Resource Conservation and Recovery Act of 1976*
TRIM	Tikhonov Regularized Inverse Method
WMA	waste management area

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1 Purpose

The purpose of this environmental calculation is to estimate hydraulic gradients and groundwater flow velocities at Hanford Site *Resource Conservation and Recovery Act of 1976* (RCRA) facilities in 2018.

2 Methodology

Except for the 200 East Area, hydraulic gradients were determined via trend-surface analysis of measured data or estimated from a water-table map. Water-level data were analyzed by trend-surface analysis calculations in a Microsoft Excel 2016® spreadsheet using a method described by Davis, 2002, *Statistics and Data Analysis in Geology*. A first-order, linear trend surface (i.e., a plane) was fitted to the water-level elevation data using least squares regression. The slope of the fitted surface represented the hydraulic gradient magnitude, and the dip direction represented the hydraulic gradient direction. To determine if the fitted planes were valid for determining the hydraulic gradient, statistical tests were used to evaluate the goodness of fit of the planes to the water-level data. Details of this method were previously described in ECF-Hanford-16-0013, *Hydraulic Gradients and Velocity Calculations for RCRA Sites in 2015*, and will not be repeated here.

Hydraulic gradients for 200 East Area RCRA units are described in a separate calculation using the Tikhonov Regularized Inverse Method (TRIM): ECF-200E-18-0085, *Water Level Mapping and Hydraulic Gradient Calculations for 200 East Area RCRA Sites, 2018.*

The average linear velocity of groundwater was calculated using a form of the Darcy equation:

$$\bar{v} = \frac{Ki}{n_e} \qquad \text{Equation 1}$$

in which $\bar{v}$ is average linear velocity, K is hydraulic conductivity, i is hydraulic gradient, and n_e is effective porosity.

At Low-Level Burial Ground (LLBG) Waste Management Area 4 (WMA-4), the water table is perturbed by groundwater extraction and injection and a planar surface could not be fitted to the data. The direction of groundwater flow was estimated from the March 2018 water table map (ECF-Hanford-18-0048, *Preparation of the March 2018 Hanford Site Water Table and Potentiometric Surface Maps*). The magnitude of the gradient was estimated from the spacing of the contours coupled with measured water levels.

3 Assumptions and Inputs

Water-level data were retrieved from the Hanford Site "Environmental Dashboard Application" (EDA; https://ehs.hanford.gov/eda/) for wells screened across the water table near RCRA WMAs. Calculations were performed for March 2018 and, in many cases, for additional time periods.

Well coordinates (northing and easting) were retrieved from EDA. The data are provided in the electronic spreadsheet files that accompany this calculation (Appendix A).

For each unit in the 200 East Area, the average gradient magnitude and azimuth from ECF-200E-18-0085 were used to estimate groundwater velocity using Equation 1. They are based on monthly measurements from May through September 2018 from the 200 East Area low-gradient monitoring network.

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The trend surface analysis assumes that the water table is planar. This is of course a simplification, because water table contours form a varied “topography.” Thus, the hydraulic gradient calculation provides an average result.

As applied here, the Darcy equation assumes that flow is horizontal (vertical gradients are insignificant) and the aquifer is homogeneous. Table 1 lists hydraulic parameters and their sources.

4 Software Applications

A Microsoft Excel 2016® spreadsheet was used to perform calculations described in Section 2, using the default calculation formulae available in that software. The hydraulic gradient spreadsheet previously was validated by comparison of results with a commercial software (Weier, 2008, “Spreadsheet Verification”).

5 Calculations

Table 1 of ECF-Hanford-16-0013 illustrates the Excel spreadsheet and its formulae. The same formulae were used for the 2018 calculations, and they are included in the electronic spreadsheet that accompany this calculation (Appendix A).

6 Results

Table 1 summarizes results of the hydraulic gradient and velocity calculations. The paragraphs below provide additional information where needed.

No meaningful gradient could be calculated for the 183-H Solar Evaporation Basins in 100-H Area in 2018. The natural direction of groundwater flow is toward the east (toward the Columbia River), but pump and treat (P&T) extraction and injection wells are located on all sides of the RCRA unit. Several different water-level data sets were evaluated, but no meaningful results were obtained from trend surface analysis, nor could the gradient be inferred from the March 2018 water table map.

At LLBG WMA-3 and -4, the gradient is affected by mounding from P&T injection wells. At LLBG WMA-3, a gradient was calculated based on a set of wells downgradient of the southern part of the WMA. At LLBG WMA-4, data do not allow for trend surface analysis, so the direction and magnitude of the gradient were estimated from the March 2018 water table map.

Groundwater extraction wells west and east of WMA TX-TY affect local flow directions. Trend surface analysis provided a general gradient direction and magnitude.

Beneath the west part of the 216-B-3 Pond, the uppermost aquifer is unconfined and the gradient was estimated via TRIM. The unconfined aquifer is not present beneath the east part of 216-B-3 Pond, and the uppermost aquifer is a confined unit in the Ringold Formation. The gradient for the confined aquifer was calculated based on water-level data from three wells.

The unconfined aquifer beneath the integrated disposal facility (IDF) includes both Hanford and Ringold sediments. Hydraulic conductivity values and the resultant velocity estimates for the two units vary by four orders of magnitude. The same hydraulic gradient, determined via TRIM, was used in both calculations.

Table 1. Results of Gradient and Velocity Calculations

WMA	Method	Date (2018)	v min (m/d)	v max (m/d)	Gradient (m/m)	Direction (degrees east of north)	Goodness of Fit (R^2)	Correlation Coefficient (R):	P-Value	Hydrologic Properties (references)	Comments
1301-N	Conventional	March	0.007	0.13	3.6E-04	21	0.95	0.98	0.0477	K = 6.1 to 37 m/d (PNL-8335); n_e = 0.10 to 0.30	Influenced by 100-K injection wells.
		Sept.	0.062	1.1	3.0E-03	325	0.96	0.98	0.0418		
1324-N/NA	Conventional	March	0.011	0.19	5.2E-04	37	0.098	0.099	0.0193	K = 6.1 to 37 m/d (PNL-8335); n_e = 0.10 to 0.30	Influenced by 100-K injection wells.
1325-N	Conventional	March	0.011	0.20	5.5E-04	349	0.99	1.00	0.0000	K = 6.1 to 37 m/d (PNL-8335); n_e = 0.10 to 0.30	
		Sept.	0.018	0.32	8.7E-04	355	0.74	0.86	0.0333		
183-H	None	--	--	--	--	--	--	--	--	K = 15 to 140 m/d (PNL-6728); n_e = 0.10 to 0.30	Not calculated. In cone of depression of P&T extraction wells.
216-A-29	TRIM	May-Sept	1.6	1.6	1.9E-05	154	N/A	N/A	N/A	K = 17,000; n_e = 0.2 (CP-57037)	
216-A-36B	TRIM	May-Sept	0.0006	0.0006	1.9E-05	125	N/A	N/A	N/A	K = 3.26; n_e = 0.1 (assumed)	
216-A-37-1	TRIM	May-Sept	1.5	1.5	1.8E-05	135	N/A	N/A	N/A	K = 17,000; n_e = 0.2 (CP-57037)	
216-B-3 Ringold	3-point plane	March	0.066	0.066	1.3E-03	229	N/A	N/A	N/A	K = 5 m/d; n_e = 0.1 (CP-57037)	Data from 3 wells screened in confined Ringold

Table 1. Results of Gradient and Velocity Calculations

WMA	Method	Date (2018)	v min (m/d)	v max (m/d)	Gradient (m/m)	Direction (degrees east of north)	Goodness of Fit (R^2)	Correlation Coefficient (R):	P-Value	Hydrologic Properties (references)	Comments
216-B-3 Hanford	TRIM	May-Sept	1.2	1.2	1.4E-05	184	N/A	N/A	N/A	K = 17,000; n_e = 0.2 (CP-57037)	Gradient assumes same as 216-A-29 Ditch
216-B-63	TRIM	May-Sept	0.38	0.38	4.5E-06	130	N/A	N/A	N/A	K = 17,000; n_e = 0.2 (CP-57037)	
216-S-10	Conventional	March	0.16	0.16	3.2E-03	105	0.99	1.00	0.0079	K = 5 m/d; n_e = 0.1 (CP-47631)	
300 APT	Conventional	February	18	18	3.3E-04	145	0.97	0.99	0.001	K = 9,000 m/d; n_e = 0.17 (PNL-17708)	
IDF	TRIM	May-Sept	2.7E-04	2.8	1.7E-05	79	N/A	N/A	N/A	K = 3.26 (Ringold) to 17,000 (Hanford); n_e = 0.01 to 0.2 (CP-57037)	Aquifer includes both Ringold and Hanford
LERF	Conventional	January, March, June	0.15	0.15	3.7E-04	174	0.98	0.99	0.0198	K = 39.5 m/d (DOE/RL-2013-46); n_e=0.1 (assumed)	Average of gradients calculated for January, March, and June
LLBG WMA-1	TRIM	May-Sept	2.2	2.2	2.6E-05	112	N/A	N/A	N/A	K = 17,000; n_e = 0.2 (CP-57037)	
LLBG WMA-2 east	TRIM	May-Sept	0.040	0.18	5.3E-06	150	N/A	N/A	N/A	K = 1,500 to 6,700 m/d (PNL-6820); n_e = 0.2 (CP-57037)	
LLBG WMA-2 west			0.45	0.45						K = 17,000 m/d west (CP-57037);	

Table 1. Results of Gradient and Velocity Calculations

WMA	Method	Date (2018)	v min (m/d)	v max (m/d)	Gradient (m/m)	Direction (degrees east of north)	Goodness of Fit (R^2)	Correlation Coefficient (R):	P-Value	Hydrologic Properties (references)	Comments
										n_e = 0.2 (CP-57037)	
LLBG WMA-3	Conventional	March	0.37	0.37	7.4E-03	101	0.99	0.99	0.0016	K = 5 m/d; n_e = 0.1 (CP-47631)	Gradient east of Trenches 31 and 34
LLBG WMA-4	Map estimate	March	0.43	0.43	8.6E-03	90	N/A	N/A	N/A	K = 5 m/d; n_e = 0.1 (CP-47631)	Gradient estimated from water table contours
NRDWL	Conventional	March	0.033	0.033	6.1E-05	84	0.89	0.94	0.0000	K = 109 m/d; n_e = 0.2 (CP-57037)	
WMA A-AX	TRIM	May-Sept	0.97	0.97	1.1E-05	145	N/A	N/A	N/A	K = 17,000; n_e = 0.2 (CP-57037)	
WMA B-BX-BY	TRIM	May-Sept	0.26	0.28	3.0E-06	142	N/A	N/A	N/A	K = 17,000 to 18,800 m/d; n_e = 0.2 (CP-57037, DOE/RL-2015-75)	
WMA C	TRIM	May-Sept	1.2	1.2	1.4E-05	158	N/A	N/A	N/A	K = 17,000; n_e = 0.2 (CP-57037)	
WMA S-SX	Conventional	March	0.17	0.17	3.4E-03	82	0.91	0.95	0.0000	K = 5 m/d; n_e = 0.1 (CP-47631)	
WMA T	Conventional	March	0.36	0.36	7.1E-03	107	0.97	0.98	0.0002	K = 5 m/d; n_e = 0.1 (CP-47631)	

Table 1. Results of Gradient and Velocity Calculations

WMA	Method	Date (2018)	v min (m/d)	v max (m/d)	Gradient (m/m)	Direction (degrees east of north)	Goodness of Fit (R^2)	Correlation Coefficient (R):	P-Value	Hydrologic Properties (references)	Comments
WMA TX-TY	Conventional	March	0.48	0.48	9.5E-03	86	0.97	0.99	0.0275	K = 5 m/d; n_e = 0.1 (CP-47631)	Water table influenced by extraction wells. Calculated gradient provides general, overall direction and magnitude.
WMA U	Conventional	March	0.31	0.31	6.2E-03	85	0.98	0.99	0.0000	K = 5 m/d; n_e = 0.1 (CP-47631)	

Sources:

CP-47631, *Model Package Report: Central Plateau Groundwater Model Version 8.3.4.*

CP-57037, *Model Package Report: Plateau to River Groundwater Transport Model Version 7.1*.

DOE/RL-2013-46, *Groundwater Monitoring Plan for the Liquid Effluent Retention Facility.*

DOE/RL-2015-75, *Aquifer Treatability Test Report for the 200-BP-5 Groundwater Operable Unit.*

PNL-6728, *Geohydrologic Characterization of the Area Surrounding the 183-H Solar Evaporation Basins*.

PNL-6820, *Hydrogeology of 200 Area Low-Level Burial Grounds—An Interim Report*.

PNL-8335, *Application of Three Aquifer Test Methods for Estimating Hydraulic Properties within 100-N Area.*

PNNL-17708*, Three-Dimensional Groundwater Models of the 300 Area at the Hanford Site, Washington State.*

IDF = integrated disposal facility

K = horizontal hydraulic conductivity

LERF = Liquid Effluent Retention Facility

LLBG = low-level burial grounds

NRDWL = Nonradioactive Dangerous Waste Landfill

N/A = not applicable

n_e = effective porosity

Table 1. Results of Gradient and Velocity Calculations

WMA	Method	Date (2018)	v min (m/d)	v max (m/d)	Gradient (m/m)	Direction (degrees east of north)	Goodness of Fit (R^2)	Correlation Coefficient (R):	P-Value	Hydrologic Properties (references)	Comments

P&T = pump and treat

TRIM = Tikhonov Regularized Inverse Method (ECF-200E-18-0085, *Water Level Mapping and Hydraulic Gradient Calculations for 200 East Area RCRA Sites*)

v = average linear velocity

WMA = waste management area

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Appendix A

Microsoft Excel® tables are provided on the removable media.

Microsoft Excel Spreadsheet
Gradients_2018.xlsx

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